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ECONOMICAL USE OF REINFORCED BRICK MASONRY

INTRODUCTION

The addition of reinforcing steel to clay masonry to form reinforced brick masonry (RBM) is increasing as a method of structural design. It has been used primarily as a method of developing additional resistance to lateral forces, for the most part in designs where such loads as high winds, earthquakes, possible blasts, or lateral forces from surcharges are indicated.

RBM has been used to a much less degree as a method of increasing the allowable slenderness ratio of masonry walls and columns subjected to normal structural loads. In other words, a somewhat thinner and lighter masonry section can often be used if reinforcing is added. Following this line of reasoning one step further, it becomes apparent—assuming constant loads and wall thickness—that reinforcing a masonry wall makes it possible to build the wall considerably higher and with less lateral support than would be possible without reinforcement.

The economies of such construction are obvious; first the reduction in wall thickness means a proportionately lighter wall section. Also with a thinner wall, there is a certain gain in usable floor area. The savings in materials and greater freedom of design, together with other advantages, may justify RBM in a number of buildings which otherwise would have no excessive lateral force requirements to indicate its use.

WALL TYPES

Reinforcement of masonry wall sections may be applicable in several different types of walls. It may prove economical in bearing walls, with or without pilasters (in some cases reinforcement may eliminate the need for pilasters entirely), or in non-load-bearing walls, both interior and exterior, if calculations indicate that an economy will result.

Bearing Walls. A masonry wall will seldom be subjected to only one type of stress. Bearing walls most generally are masonry walls which, as their major structural function, must support some of the dead and live loads of the structure. This compressive load, particularly in exterior walls, is usually applied at a point other than the center of the wall section. The loading is therefore eccentric and a certain amount of moment will be induced in the wall. This fact is apparent when it is realized
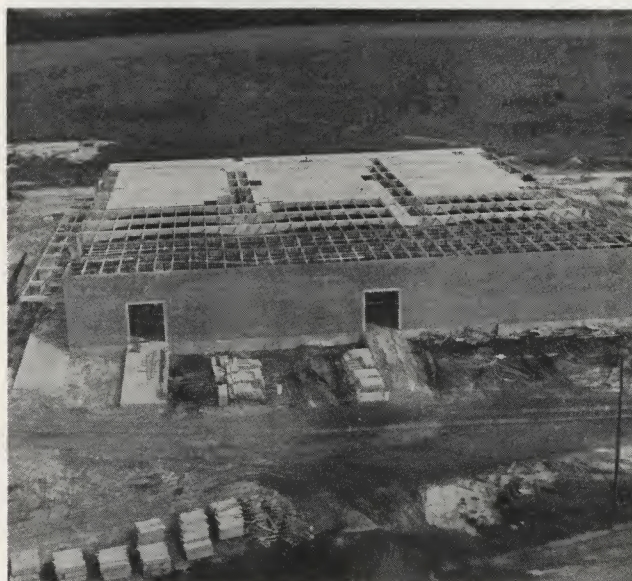

FIG. 1

Construction photo of Group Squadron Warehouse, Peter Field Point, North Carolina. One of the RBM walls may be seen in the foreground.

that a concentrated vertical load placed on a wall one-third of the distance from the interior face will develop twice the unit stress at the interior face as would a load placed at the center of the same wall. The unit stress so developed will have a direct effect on the capacity of the wall, since masonry is limited by code to maximum unit design stresses considerably less than its ultimate strength.

As the wall increases in height, there is normally a reduction in the allowable unit stress which may be utilized in the design. In RBM column design, this is taken into consideration through the use of the formula:

$$P' = P\,(1.3 - 0.03\,h/d)$$

which is used when the h/d or slenderness ratio exceeds 10. In this formula "P" equals the maximum allowable axial load and "P'" equals the net or reduced load. The length or unsupported height of the column or wall is indicated by "h" and "d" equals the least lateral dimension.
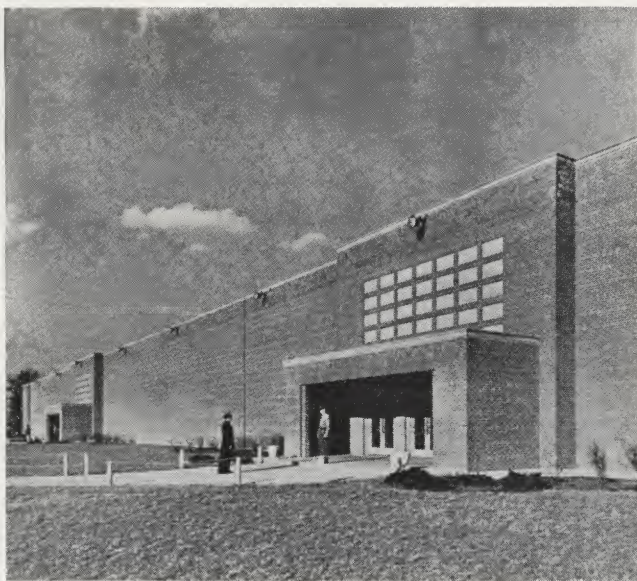
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FIG. 2

Exterior view of the Naval Bomb Site Factory at Indian-
apolis, Indiana, showing high windowless RBM walls used
in blast-resistant construction.

The difference between maximum unsupported
wall heights for reinforced masonry and those for
unreinforced masonry is considerable—in some cases
the addition of steel makes it possible to more than
double the height of a wall, assuming all other
conditions constant. Although, as shown in Table 2,
code restrictions do not allow full utilization of
the additional strength, an appreciable gain is still
possible. For example, an 8-inch unreinforced load-
bearing exterior wall is limited to an unsupported
height of 13 ft. 4 in. by the ASA Code, but may be
built to 16 ft. 8 in. if reinforcing is used. If good
engineering practice is the only limiting factor, the
same wall may be built to a height of 33 ft. 8 in.
without lateral support. This fact may find practical
application in several forms of contemporary work.
For example, the bearing walls of an auditorium or
gymnasium in most schools are in excess of the height
allowed for 8-in. masonry unless lateral support is
provided. The use of intersecting walls or pilasters
is sometimes architecturally undesirable and a more
economical solution might be found in RBM.

Non-load-bearing Walls. These walls, differ from
the above type in that they are not designed to resist
any compressive forces from the structure or its live
loads. A non-load-bearing wall may be in the form
of a panel or curtain wall; it may be free-standing or
it may be supported on all sides by other parts of the
structural system. Although its name implies a lack
of structural function, it often must assume a certain
amount of stress. Panel or curtain walls located on
the exterior of skeleton-framed buildings must be
designed for wind loading. Such walls, because of
the lack of compressive stress, are less stable from a
design standpoint than similar walls which are
subjected to a compressive load. A masonry wall in

compression has additional resistance to lateral loads
in much the same manner that a prestressed member
has additional lateral or flexural strength as com-
pared with one with no prestressing.

Another common force to which non-structural
masonry walls are subjected is that of diagonal
tension or shear. It usually results from a lateral
force being applied against a wall or plane normal to
the wall in question. The stress is transmitted to
the masonry wall as a longitudinal horizontal force.
Interior partitions, end, or transverse walls in many
buildings fall into this category, since they must act
to resist lateral forces resulting primarily from wind.

In certain types of occupancies, provision must be
made for other loads to be assumed by non-load-
bearing walls. Impact is often an important factor
in industrial or commercial work—particularly in
warehousing areas. It therefore becomes apparent
that, even in walls where there is no direct com-
pressive load, there may easily be justification for
considering reinforced masonry as a purely economic
measure.

Columns and Piers. A third general classifica-
tion of masonry which should be covered separately
consists of columns and piers. They are alike except
that a pier is limited to a slenderness ratio of less
than 10 to 1, while that of a column exceeds 10 to 1.

In unreinforced or plain masonry, there is usually
a rather conservative limitation imposed by building
regulations upon the use of this type of construction.
Generally, no unreinforced masonry columns are
permitted; that is, the slenderness ratio (ratio of
unsupported height to least cross-sectional dimen-
sion) is limited to 10 to 1. Through the use of rein-
forcement, much taller and more slender sections
are permitted with an allowable unit stress which
may vary in relation to the height and cross-section
of the member in question.

Masonry columns have been found practical for
use in a number of different designs, due to their
relatively low cost and architectural qualities.

Their design is not complicated. The procedure is
similar to that for reinforced concrete columns, and
is the basis for RBM bearing wall design. The use of
lateral ties in reinforced brick masonry columns will
sometimes enable the longitudinal steel to more
closely approach its ultimate strength and thereby
slightly increase the strength of the column.

TEST DATA

Considerable test data concerning the strength of
reinforced brick masonry walls, beams, and columns
are available. Most of the information deals pri-
marily with strength in flexure and related factors,
such as bond and shear strengths, but there is
information on the results of tests which indicate
the relative increase in compressive strength of
masonry columns and walls through the use of steel
reinforcement of different types and amounts.

In one series of tests conducted at the University
of Wisconsin and reported by Professor M. O.
Withey in the paper, "Tests on Reinforced Brick
Masonry Columns," ASTM Proceedings, Vol. 34,

TABLE 1

Unit Stresses Carried by Brickwork and Steel in Columns

| Column | Gross Area | Percentage of Reinforcement | | Maximum Load | Unit Stress |
		Longitudinal	Lateral		
	sq. in.	%	%	lb.	psi
No. 1	157.5	0	0	154800	983
No. 4	161.3	1.93	0	255000	1580
No. 6	162.6	3.83	0	428800	2640
No. 14	161.3	1.93	0.75	322200	2000
No. 15	162.5	3.83	0.74	461750	2840
No. 25	152.0	4.10	1.50	768700	5050
No. 30	162.0	0	0	542000	3340
No. 32	154.6	2.01	0.80	712200	4610

Part II, there were 32 columns tested. These columns were approximately 12½ in. square and 6 ft. high. Two types of brick and two types of mortar were tested, and, as may be seen from Table 1, the masonry materials and inclusion of reinforcement had a very definite effect on the ultimate strength of the columns. Table 1, which is a condensation of the tabular data published in the report, lists the results of tests on eight columns. The last three listed were built with high strength brick and mortar, while the others were composed of much lower strength masonry materials. Lateral reinforcement was in the form of ⅜-in. hoops 8 or 10 in. in diameter. The data in Table 1 serve to illustrate the relative strength of masonry under a compressive loading with and without reinforcement.

DESIGN

In order to demonstrate the additional height to which a masonry wall may be built through the use of reinforcing, comparison data are presented in Table 2. This table, which is limited to an 8-inch wall, compares the allowable unsupported heights for such a wall under good current masonry codes, both reinforced and unreinforced, with the maximum height to which the wall may go if limited only by the designer's calculations.

In computing the maximum unsupported heights, shown in Column 3, the masonry is assumed to have an ultimate strength of 2,000 psi and using an f_m in flexure of 0.33 f'_m, a maximum compressive stress of 660 psi was obtained. To this was added an additional 33% which is customary practice when dealing with transitory loadings such as wind, making the maximum design stress 880 psi.

With sufficient steel to just exceed that required for a balanced design, the wall will fail by crushing in the extreme fibre of masonry and the limiting factor will be the resisting moment of the masonry:

$$M_m = \frac{f_m bd^2}{6}$$

Assuming partially restrained ends, the bending moment due to wind will be $\frac{wl^2}{10}$. These two expressions may be set equal to each other and solved for the wall height at which the maximum compressive stress would reach the allowable. Such a procedure, however, would neglect the weight of the wall itself or any axial compressive stress from above. A modification of the above principal has been used as shown below.

$$f_m = \frac{6wh^2}{(144)\,10bd^2} + \frac{ph}{2\,(144)}$$

f_m = allowable unit stress in masonry (allowable compression, flexural)—psi
w = unit load due to lateral force (wind)— psf
h = maximum unsupported height (or length if limiting dimension is horizontal)—ft.
p = unit weight of wall—lb/cu. ft.
b = width of section in question (12 in.)
d = effective depth—in.

If additional weight is to be supported by the wall this must, of course be added to the equation as an independent expression. This equation, when solved for h, will give the maximum height to which the wall may be built without lateral support. The method is based on the assumption that sufficient steel will be used to develop maximum design stresses in the masonry. Under certain circumstances this may not be practical. Steel requirements should always be determined, therefore, in the preliminary stages of design.

EXAMPLES

There are many examples of reinforced brick masonry which have been designed not only as a means of solving engineering or economic problems, but also as a method of construction whereby architectural and structural effects otherwise impossible might be achieved. Reinforced brick masonry walls and columns—tall and slender and yet structurally stable—are to be found in all parts of the country.

The Lunt-Lake Apartment buildings, designed by Pace Associates, Holsman, Holsman, Klekamp and

TABLE 2

Maximum Unsupported Heights for 8-inch Exterior Brick Walls ([1])

| Loading lb./lin. ft. | Code Limitations | | By Design ([5]) |
	Unreinforced	Reinforced	Reinforced
No Load	13' -4" ([2])	20' -0" ([3])	34' -0"
800	13' -4"	16' -8" ([4])	33' -10"
1800	13' -4"	16' -8"	33' -8"

(1) Assume 20 psf wind load
(2) Based on 20 to 1 ratio of unsupported height to thickness
(3) Based on 30 to 1 ratio of unsupported height to thickness
(4) Based on 25 to 1 ratio of unsupported height to thickness
(5 See text for explanation of method used.

Taylor, and Frank J. Kornacker, were constructed in Chicago, Illinois in 1950. These are nine stories high and of wall bearing construction with 10½ inch rowlock RBM for the first story and 8-inch rowlock RBM for the remainder of the height. As might be expected, the compressive strength of masonry is used in this project to a much greater degree than is common. It is extremely important under such circumstances that careful quality control be maintained—both on materials and workmanship—during all phases of construction.

Another example in a different type of structure may be found in the Group Squadron Warehouse at Peter Field Point, North Carolina. Designed by Six Associates of Asheville and built in 1953, this building is an excellent example of the use of RBM to build a relatively high, long and laterally unsupported wall. The wall itself, which was designed to withstand a 100 mph wind, is 10½ inches thick of rowlock RBM and is 23 feet from the floor to the bottom of the purlins which provide lateral support. A general view of the building during construction is shown in Fig. 1.

A third example which is illustrated in Fig. 2, is the Naval Bomb Site Factory at Indianapolis, Indiana. This is an air-conditioned, windowless building, 500 feet by 1000 feet in area with reinforced brick curtain walls approximately 40 feet high. Here is a structure which makes use of the lateral resistance of reinforced brick masonry to allow relatively high, thin laterally unsupported masonry walls in a design intended to resist bomb blast.

CONCLUSION

This issue of *Technical Notes* has been devoted to a discussion of a broader application of the principles of reinforced brick masonry. It has been stated that the use of reinforcing steel, enabling the masonry itself to work more effectively, may often result in an economy which merits consideration. The use of reinforcement makes possible almost unlimited shapes and forms for structural design. It enables the designer to combine the architectural and maintenance-free qualities of clay masonry with the freedom of expression and flexibility of proportion heretofore not possible.

No attempt has been made in this paper to cover the design procedure involved in RBM. It is not complex, however, and those who are familiar with reinforced concrete design find RBM similar in nature and relatively simple to handle.

For an authoritative discussion of reinforced brick masonry the reader is referred to "Reinforced Brick Masonry and Lateral Force Design" by Plummer and Blume which is available through the Structural Clay Products Institute and its affiliated regional organizations.

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